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TREATMENT AND DISPOSAL OF ATOMIC ENERGY INDUSTRY WASTES

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TREATMENT AND DISPOSAL OF ATOMIC ENERGY INDUSTRY WASTES

Joseph A. Lieberman[1] and Arthur E. Gorman,[1] M. ASCE

Industrial management in the United States has come to appreciate that a liberal, farsighted policy in waste disposal and environmental sanitation has many advantages over the old fashioned "do as you please" attitude that once was commonplace. Most industries which followed this policy now realize it was shortsighted and their numbers are fast diminishing. In contrast, today we find specialists such as medical directors, industrial hygienists, sanitary engineers, chemical engineers and biologists in industry conducting important research in waste disposal. Also, they hold important committee memberships in professional societies which are leading the way to a newer and mutually profitable relationship between industry and public agencies responsible for the health, safety and welfare of our people and protection of our natural resources. The purpose of this paper is to point out some of the methods presently used in handling and disposing wastes in the atomic energy industry; also to report how waste disposal problems are being worked on both within and outside the industry and with the cooperation of public agencies, universities and other industries.

Rapid Growth of Atomic Energy Industry

The atomic energy industry with its unprecedented expansion program is in fact rather a late-comer in a well integrated industrial, economic and social community. This in addition to the uniqueness of its operations and its product, the lack of general knowledge of the industry's technology and terms, the secrecy which necessarily must be maintained and the fact that by act of the Congress the industry is under government control, places a more than ordinary responsibility on sponsors of the industry.

It is no simple task for a new industry to compress in a few years research and development that would normally take decades. The effort in waste disposal and environmental sanitation is to prevent, for this industry and the public, many of the headaches which others have experienced and to do this without blocking progress while the industry is developing at an unprecedented rate.

Cooperation with Outside Agencies

The AEC has elected to evaluate and to seek solutions of its problems by enlisting the aid of experienced, well established Federal agencies which for many decades have been working on similar problems with other industries. In particular, these agencies are the Geological Survey, the Weather Bureau, the Public Health Service, the Corps of Engineers, and the Bureau of Mines.

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Specialists from these agencies are working on specific problems and in many areas. They are being indoctrinated in the various facets of the atomic energy industry. In turn the staff of AEC and its contractors are benefiting by the advice, experience and continuing interest of these agencies. Much of the work is done under contract with the AEC. In some cases, however, the cooperating agencies have assigned technicians for service with AEC or its contractors without reimbursement.

Research and development contracts in sanitary engineering have been placed at a number of universities, private research institutions and National Laboratories serving the industry. The universities now working on such contracts include California, Harvard, Illinois, Johns Hopkins, New York, Texas, and the Massachusetts Institute of Technology.

The Commission follows the practice of conferring with state officials having responsibility for preventing pollution of the atmosphere, ground and surface waters in the disposal of wastes from industry. In several areas it participates through its staff and its contractors in advisory committees on which are represented Federal, state and local officials. Usually the members of the committee are invited to visit AEC production or research areas where they are informed as to processes and waste disposal methods and are asked to submit criticisms and suggestions. Such advisory committees are in existence in relation to activities at the Hanford and Savannah River Works, at the Knolls Atomic Power Laboratory near Schenectady, and one is under development for the National Reactor Testing Station in Idaho. Visits to the Argonne, Oak Ridge, and Brookhaven National Laboratories have been made by representatives of the Illinois, Tennessee and New York State Departments of Health, respectively. The Ohio River Valley Water Sanitation Commission has been given information concerning nine major AEC projects in that valley. This was supplemented by a visit to five of these plants by three security cleared representatives of ORVWSC.

Disposal of Wastes

Low Level Wastes

By far the largest volume of wastes from this industry are low in radioactivity and toxicity. It is the practice to hold and to monitor liquid wastes of this sort before they are released to the ground, to waterways or to public sewers, in order to be certain that their levels of activity are within prescribed limits of safety. Wastes produced in substantial volumes and whose levels of activity exceed safe limits present a real problem both in treatment and cost. Typical of such wastes are effluents from laundries handling garments contaminated by radioactivity, drainage from laboratory sinks in research areas where radioactive materials are used, wash water from decontamination processes, and water used in basins to shield operators from radioactive materials being stored or worked on.

Until more complete knowledge of the long term effects of the release of atomic wastes is gained, a conservative policy has been adopted as to the degree of decontamination required. In the interest of economy, research is underway to find better and less expensive treatment systems for large volumes of low level wastes than evaporation and ion exchange which are the principal methods now used in treating high level wastes. Work also is being done to evaluate the subsequent dilution factors in nature which may be taken advantage of and thus reduce the degree of treatment required. Other industries use

these dilution factors, and the indices for evaluating them in relation to many industrial wastes are reasonably understood by public officials having responsibility for protecting the public health and our national resources. Generally, this is not the case in dealing with radioactive wastes although as research proceeds some of the needed parameters are being established and recognized. The possibility of using biologic methods such as those used by sanitary engineers in treating domestic sewage and industrial wastes is being studied at several universities under AEC contract. As examples, at New York University the feasibility of using the trickling filter process for decontaminating laundry wastes at the Knolls Atomic Power Laboratory is being investigated; the activated sludge process as a means of removing radioactivity from waste streams is under study at the University of California; the effect of radioactivity on anaerobic digestion of sewage sludges is the subject of research at the University of Illinois; at the University of Texas studies are underway to determine the extent to which algae in streams or ponds could be used to take up radioactivity in low level wastes.

The long half life of certain radioactive materials makes it essential that the effect and probable ultimate fate of wastes from this industry be carefully appraised before they are released in any significant quantities into the ground, the air, surface waterways or the sea. The importance of this time factor constitutes a significant difference between wastes of the atomic energy and most other industries. Chemical, biological and bacterial contaminants when released are subject to substantial changes in nature usually in hours or days, depending on the environment they are exposed to. Ordinarily, with time these contaminants become progressively less obnoxious or hazardous, depending on their origin. On the other hand, a radioactive waste is definitely tagged as to the period it will emit radioactivity. In the case of long lived elements the prolonged period of hazard from radioactivity places a responsibility on one who disposes of such wastes which cannot be dealt with lightly.

The property of many inert materials and living things in nature to take up and to hold radioactivity is one of the most important factors in evaluating the capacity and limitation of various methods of disposal of low level liquid wastes. The phenomenon is exceedingly important and needs to be better understood. Disposal on or into the ground through surface leaching pits, lagoons, cribs or reverse wells must to a considerable degree be governed by the capacity of the upper soils to take up radioactivity prior to passage of the liquids downward to the water table.

The Geological Survey is obtaining soils from all major AEC areas of operations and at many other places in this country for the purposes of classifying these soils as to their decontaminating properties and limitations. Further studies are being conducted at Yale University and AEC National laboratories. The objective is to learn more about these materials especially their physical structure and properties which may account for ability to remove and perhaps fix radioactivity from water and waste streams. Resolving this problem will call for much team work on the part of the geologist, the minerologists, the physical chemist, and the nuclear physicist and chemist. Once this phenomenon and its limitations are understood the method could then be applied in many water decontamination and waste disposal problems.

The direction and rate of movement of ground waters toward sources of downstream water supply must be given careful consideration. The degree of dilution of a contaminant released from a point source of discharge is governed by the characteristics of ground water flow. Where this flow is laminar, as is usually the case in ground water flow, the amount of dilution may not be

great. The contaminant may move in a ribbon like manner expanding only little as it migrates. This fact must be taken into consideration when monitoring wells are used in evaluating the effectiveness of a waste disposal procedure. Failure to obtain evidence of contamination is no assurance that it does not exist nor that the method of disposal followed has been effective. In the absence of good information as to the geology of the area and the characteristics of the subsoils in retaining radioactivity negative results could be misleading.

An important consideration when radioactive liquid wastes are discharged to surface waters is the ability of suspended matter and organisms in the water and at the stream bed to take up radioactivity. Often when the contaminant is radioactive the orthodox methods of stream surveying to evaluate the effects of organic pollution may not be adequate. In this case the B.O.D. of the stream is of much less importance than the sediment loading, the characteristics of the sediments and the conditions under which they are deposited and resuspended. Knowledge as to the sediments transported by a stream, its cross section, velocity and physical flow characteristics is particularly important in an evaluation of the dilution or concentration factors of a stream or river.

High Level Wastes

The volume of wastes from atomic energy operations which are high in radioactivity are relatively small in comparison with low-level wastes. From the standpoint of quantity of radioactivity the big problem in treatment and disposal of radioactive wastes is associated with the chemical processing of spent fuel from a nuclear reactor in order to recover the unburned fuel. In most of the existing reactors there are solid fuel elements and fission of the uranium 235 results in retention of the fission products within the solid element. These fission products, which constitute the waste problem, are generally solids which go into solution when the whole element is dissolved for recovery purposes. The fuel elements are ordinarily cooled for some time prior to dissolution to allow the short lived activity to decay, thereby reducing the total quantity of radioactivity to be contended with in the recovery process. In the fuel element as discharged from the reactor the mass concentration of fission products will vary from 100 to 1000 ppm. In the course of fuel recovery processing the fission product concentration is reduced by dilution with water, solvents, and other solids.

While such wastes may be processed and stored under conditions which have some parallel in other industries, the methods and facilities used, when applicable, must be surrounded by extraordinary precautions, and special materials must be used, all of which adds substantially to the cost. Obviously, the value of the product as well as its hazardous properties has a direct relationship to the investment which can be made in a facility to store, treat, and dispose of a radioactive or toxic waste. But, regardless of value, the cost of treatment to render the waste harmless is a proper charge against the industry and must eventually be reflected in the cost of the product. Obviously, the solution of the cost problem lies in research and development and not in cutting corners and exposing the industry to criticism and others to hazards. In some industries, as a result of research, profits have been made from waste products, but this is the exception rather than the rule. A capricious attitude by industry in the disposal of long lived radioactive wastes could seriously affect the national resources.

Methods of Waste Treatment

Storage in Tanks

At production plants high level and long lived radioactive wastes have been and are being stored in underground tanks at costs ranging from 50 cents to over $2.00 per gallon. Some of these wastes have reclamation value and research is being carried out to determine the feasibility of recovering important products contained in them. In the meantime high level wastes are being stored in tanks built of materials which will resist forces of corrosion from within and without. It is expected that they will remain tight for many decades. Provision is made for monitoring so that the first evidence of leakage will be detected. The hazard of minute leaks could be minimized by intelligent preventive measures. If, however, the first leak were merely a portent of a generally defective condition of the container a serious situation might follow. That is why great care is taken in selecting the location of a waste storage facility; why the geology of the area is carefully studied in advance of construction and thereafter; and why the downstream potentialities for affecting ground water are carefully appraised against the contingency of a slow leak or a serious accident which might conceivably release large volumes of waste to substrata.

So long as long lived radioactive materials are stored under ground there will be need for supervision over these wastes. Such supervision may be required for generations. Policies, procedures and products may change but these waste products cannot be forgotten or neglected.

Evaporation

With high level wastes containing more than 10^{-5} curies per liter and less than 10 percent solids, evaporation is effective in reducing the volume of "hot" material to be handled and in distilling off the water which may be discharged to nature or re-cycled as process water. When the concentrate is stored as a liquid the evaporation is carried to roughly 30 percent solids. At one installation the concentration is carried to 50 percent solids or more. This concentrate will solidify when cooled in a suitable container. It is a relatively expensive process however, with costs in the neighborhood of 4 to 8 cents per gallon. The cut-off point at which some other less expensive process should be used must be decided with much care. The high level of radioactivity in the residues of evaporators necessitates storage in containers which are shielded until sufficient decay takes place to permit safe handling for ultimate disposal. Using evaporation the radioactivity in the water being discharged can be reduced by a factor of 10^3 to 10^7 (decontamination factor of 10^3 to 10^7) over the amount of radioactivity contained in the feed.

Ion Exchange

The use of ion-exchange materials is another means of decontaminating wastes of various levels of activity. It has limitations and presents the problem of ultimate disposal of the spent material. One of these limitations is that it is not very effective where dissolved solids in the waste stream exceed 500 ppm. Depending on the characteristic of the contamination and salt content decontamination factors from 10 to 10^4 are possible.

At some installations ion exchange is used to decontaminate canal water (water used for shielding in fuel element storage pits).

Co-Precipitation

Co-precipitation processes in multiple cycles using coagulants are still a third method of decontamination. Usually the sludges which are formed are given further treatment and are partially dewatered for storage pending ultimate disposals. In wastes having less than 10^{-4} or 10^{-5} curies per liter and more than 0.1% salt content a coagulation, settling, filtration process quite similar to that used in a standard water treatment plant is probably more economical than evaporation or ion-exchange. Decontamination factors of 10 to 10^4 are possible. Since volume reductions are dependent on floc volume and not the salt content of the waste, fairly substantial reductions are possible and may be as high as 500.

Crystallization

Another waste treatment process which has been studied is crystallization. This is primarily applicable to wastes having high salt concentrations and where re-use of the salts is desirable. Series treatment may give decontamination factors up to 10^6. The method appears to be rather expensive and has not yet been applied on a production basis.

Ultimate Disposal of Radioactive Wastes

The ultimate disposal of radioactive wastes presents one of the more vexing problems of the industry. By ultimate disposal we mean here generally the return to nature and, more specifically, either land burial (or discharge into the ground) or sea disposal.

Land Burial

Some of the aspects of discharge of radioactivity to the ground have been discussed previously. It is being used, and we think successfully, at a number of remote AEC installations. It is apparent that more knowledge of the fundamental factors involved such as ion exchange, adsorption and absorption is required before much more extensive use is made of this method.

A burial ground near creviced or cavernous limestone, over a fault or in gravelly soils through which seepage water would travel rapidly is obviously not satisfactory. The soil should preferably contain material which has the property of absorbing radioactivity. The capacity and limitations of the soil in this regard should be thoroughly evaluated particularly with reference to the type of radioactive wastes which are to be released. Records should be kept as to the nature, location and activity and prior shielding of all buried material. It is important that the depth of burial be planned so that cover will give adequate shielding at the surface. Burial grounds are restricted areas and are adequately fenced against unauthorized access for the lifetime of the radioactivity.

Consideration is being given to the policy and economic aspects of establishing designated burial grounds to serve several AEC areas. The selection and layout of the burial ground should be well planned with reference to its operation. The operation itself must be carefully supervised and monitored to prevent deleterious environmental effects.

Of specific interest with respect to ultimate disposal is work being done at Brookhaven National Laboratory on the fixation of radioactive material on montmorillonite clay. Workers there have found that the exchange reaction

between the clay and the radioactive ions can be made irreversible by heating the clay, after it has taken up the radioactivity, to about 800° C. The idea is to then take the "hot" clay and bury it in a naturally occurring bed of similar material. Since the clay itself is an end-product of rock weathering, it is hoped that the radioactivity can be immobilized over periods approaching geologic time. The system feasibility has been demonstrated on a bench scale and a pilot plant to determine the engineering and economics involved is now being completed.

Sea Disposal

To date, along the Atlantic and Pacific Coasts, there has been some disposal of radioactive wastes to the sea. This practice has been limited to materials which constituted special problems of burial on land and the wastes were dumped into deep water off the continental shelf. Usually the radioactive material is surrounded by cement and the shielded mass is held in steel drums. While ocean disposal has certain advantages the adoption of this method for general practice in ultimate disposal of high level wastes needs a thorough evaluation before adoption. Recently a contract was negotiated with Johns Hopkins University to make such an evaluation and the survey phase of the work has been completed. Oceanographers, geographers, biologists and geologists with whom this problem has been discussed have raised some important points which call for much study. There is feeling that considering the limited current knowledge of the seas and their behavior, their potentialities as sources of food and minerals to serve future generations, the seeming advantages of sea disposal of long lived radioactive wastes may be outweighed by its disadvantages. An important point also is that once material is dumped into the sea essentially all control over it is relinquished.

Solid Waste Disposal

Incineration

Solid wastes may of course also be buried or disposed of at sea but because of the bulk of certain combustible materials which have become radioactive reduction of volume by incineration has been tried. Usually such materials include papers used as wipes or table covering in laboratories, contaminated clothing, carcasses of experimental animals, bench and floor covering and wall, siding, and roof covering materials. Studies at the Johns Hopkins University where wastes from use of radioactive isotopes were disposed of by burning in an ordinary institutional incinerator revealed that upward of 85 percent of the activity for certain isotopes such as P32 and Sr 90 may be recovered in the ashes. Therefore, they must be handled with care.

In order to assure complete protection of the environment the gases of combustion should be decontaminated to a low level of radioactivity. This requires costly air cleaning facilities including terminal filters of high efficiency. Experience with incinerators at the Argonne and Knolls National Laboratories and at the Los Alamos Scientific Laboratory has shown that the efficiency and operating cost of such units are items requiring much consideration. Present costs range up to 50 cents per pound of material burned. The Bureau of Mines through its Combustion Research Laboratory at Pittsburgh has made exhaustive studies of the problems involved in incineration of radioactive wastes. Its staff are now developing an incinerator which has much promise. This unit will be useful for general service at AEC production and research areas as well as

at isotope using institutions. It incorporates the use of tangential overfire air and also the use of molten caustic (solid at room temperatures) as an ash fluxing system.

Gaseous Wastes

When gaseous effluents are released to the air through high or low stacks it is important that a sustained effort be made to evaluate the atmospheric dilution which may be expected. The factor of dilution may vary widely during any day and seasonally depending on the area. A careful study of the meteorology of the specific area and the region may present a pattern of conditions on the basis of which operations involving gaseous contaminants may be directed and controlled. With such data available the degree of decontamination which may be required may be established within reasonable limits. Good meteorological data are important in arriving at decisions as to the location and height of stacks, the location of air intake with relation to exhaust system, the spacing between buildings and even the shape and configuration of buildings. Such data are also of great importance in design of heating and ventilation systems, cooling covers and in planning the sequence of construction work, storage of materials, performance limitations due to weather conditions and in evaluating work hazards which might be caused by unfavorable or extremes of weather.

Much attention and remarkable progress has been made in air cleaning within the atomic energy industry. Smokeless stacks used to release radioactive gases to elevations which will give good diffusion are common. They may even be confusing to our neighbors who never have seen smoke discharge from them. From air cooled reactors large volumes of irradiated air may be discharged to the atmosphere. The higher the temperature of the gaseous effluents the greater will be their lifting power and subsequent dilution in the atmosphere.

As in the case of the Geological Survey, the AEC has contracted with the Weather Bureau for assistance in evaluating the meteorological aspects of problems related to the release of gaseous effluents from its plants. At certain areas the prime contractor has elected to supplement this service and has staff meteorologists studying their local problems. This is the case at the Savannah River and Hanford Works and at the Argonne National Laboratory. By having available data as to meteorological characteristics over an area, much can be done to lessen the cost of air cleaning facilities. For example, if a process which results in a highly contaminated effluent can be put into operation where natural atmospheric dilution factors are at maximum effectiveness, the degree of clean up required may be relatively low in comparison with a process which must be in continuous operation. Periods of low wind velocities and prolonged inversion are critical ones and if they can be forecast and operations adjusted accordingly much can be saved in air cleaning equipment.

Experience has shown that in processes requiring a high degree of air cleanup using such facilities as the C.W.S. or AEC filters it is good practice to clean the incoming air and thus lessen the particulate load on the process air which later is to be decontaminated. In effluent cleaning by filtration roughing filters are a good investment in prolonging the service life of the more costly high efficiency units. A. D. Little, Inc. has developed an air filter for use in the industry which has an efficiency of 99.95 percent with a test aerosol (di-octylphthalate) of 0.3 microns in diameter. One type using an asbestos and craft paper filter is usable for air temperatures up to 275° F.

The cost of these units is about 5 cents per cubic foot per minute of capacity. A newer one using glass fibers has the same performance efficiencies and can treat gases at temperatures ranging from 550° to 700° F.

Dust loading in the atmosphere is an important consideration in the selection of plant location and in the selection of air cleaning equipment. Construction of roads and excavation for structures may disturb otherwise relatively stable soils and care should be taken to minimize such disturbances. Data as to particle size both in the raw air and the process effluent are essential to selection of efficient and economical air cleaning facilities. In the case of radioactive contamination information as to distribution of particle sizes, mass and activity, is extremely important. In dealing with radioactive materials considerably more attention than in most industries must be given to small size particulates even in the sub-micron ranges.

The behavior of contaminants of small size in the air, in air cleaning processes and in the human body are not too well understood. This is the reason the AEC on recommendation of its Stack Gas Working Group, sponsored publication of a "Handbook on Aerosols." This document includes selected reports on research carried out during World War II for the Office of Scientific Research which were declassified especially for this service. A research contract on the behavior of aerosols has been in progress at the University of Illinois for nearly three years and has attracted much attention among research workers in air cleaning.

There is need of better and uniform air sampling techniques and sampling paper to serve the industry. The A. D. Little, Inc. are working on the development of standards for filter papers adequate to resolve this problem.

The investment in air cleaning facilities at AEC plants is substantial. Early experience demonstrated that often standard equipment was not adequate to remove all contaminated material necessary to meet the strict standards which had been set up. To evaluate this situation and to assist those serving the industry to have more specific criteria on which to base specifications for air cleaning facilities, the School of Public Health of Harvard University, under AEC contract, has established an air cleaning laboratory where during the past three years very valuable research and testing work has been carried out. The staff of this laboratory have visited most AEC production and research areas and have made recommendations for improvements in air cleaning. In order that the results of their research may be made available to all concerned in air cleaning within the industry the Harvard group have conducted two well attended seminars on air cleaning and prepared for general distribution a Handbook on Air-Cleaning which may now be purchased from the Government Printing Office.

CONCLUSION

In conclusion, it is desired to emphasize that the environmental problems of the atomic energy industry, especially insofar as treatment and disposal of radioactive waste are concerned, are unique. They require, and are receiving, special consideration. Problems presented are the basis of much research sponsored by the AEC, its contractors, its national laboratories, private research institutions and Federal agencies. An organized effort is made to cooperate with public officials interested and concerned in these problems and to assist them in attaining a better understanding of the industry's policies, technology and terms. It is confidently believed that this is an intelligent approach. Also that as the uses of nuclear energy by private competitive industry expands the newer problems which will surely arise will be capable of solution with minimum risk to our people and our nation's resources.

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